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AUTHOR Stachel, Dina; Stavy, Ruth
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ABSTRACT

This document reports on a study of 48 kindergarten children in Israel regarding their concepts of "solid" and "liquid." Children were asked to classify a set of 30 materials into two groups (a group of 9 liquids and a group of 21 solids). About 65% could classify liquids correctly, 50% could classify rigid materials correctly, 30% related non-rigid materials to the group of solids, and only about 20% classified powders in the group of solids. The majority did not use a consistant and systematic set of criteria to classify all the materials. In addition, they tended to change their criteria during the course of classification. They used such criteria as color, weight, function, usage, and spatial relatedness. (TW)

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The Effect of Teaching on the Understanding of the Concepts 'Solid' and 'Liquid' by Kindergarten Children

Dina Stachel Ruth Stavy

Israeli Science Teaching Center, School of Education Tel-Aviv University, Tel-Aviv, Israel

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The Effect of Teaching on the Understanding of the Concepts 'Solid' and 'Liquid' by Kindergarten Children

Introduction

Our previous study concerning the development of the concepts 'solid' and 'liquid' among children aged 5-12 years (Stavy & Stachel 1984), indicated that from five years of age, children are familiar with the characteristic behavior of solids and liquids - for example, their ability to be piled up. Nevertheless, when presented with two liquids, only 20% of the kindergarten children could spontaneously recognize the similarity existing between them; not one of the children spontaneously recognized similarity between two solids. Moreover, the words "solid" and "liquid" are non existent in their vocabulary. When children were asked to classify materials into two groups - a group of liquids and a group of solids - about 65% could classity liquids correctly; 40% could classify rigid materials correctly; 30% related non rigid materials to the group of solids, and around 25% classified powders in the group of solids. Despite these results, it is noteworthy that in light of the childrens' justifications for their classification, the majority did not use a consistent and systematic set of criteria to classify all the materials; moreover, they changed their criteria during the course of classification. They used criteria such as: color, weight, function, usage, spatial relatedness etc. In the light of these findings the question was asked whether

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teaching can influence the understanding of the concepts 'solid' and 'liquid' and the ability to classify materials into these groups.

The kindergarten program in Israel is characterized by two approaches. The integrative approach and the disciplinary one. The integrative approach is based on belief in the efficiency of the activating school environment, where learning experience is centered around a focus of interest for a certain period of time; and where the children are expected to discover concepts through trial and error, while they are working with materials and using various tools whereby they will perceive the concepts (Teaching Guides 1960, 1966). In accordance with this approach, some parts of a science program were translated and implemented (Science grades K-2, 1965-66). On the other hand, the disciplinary approach emphasizes the structural methods and the significant elements of each discipline. According to this approach, a special guide in math for kindergarten children was developed (1970) which includes chapters on relational concepts, sets, cardinal numbers, etc. With regard to these two approaches, the MATAL* Early Childhood Program (Stachel, 1985) differs in its goals, content and teaching methods from the programs currently used in the kindergarten.

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It is characterized as follows:

a. The content is related to various disciplines, in contrast to programs based on a distinct disciplinary approach.

b. The internal structure of the material is reflected in a defined system of graded concepts for learning purposes, and the activities are structured with increasing levels of difficulty, in contrast to the existing programs which are based on an eclectic, unstructured approach with the concepts submerged under much diffused information.

c. The character of the program requires a change from traditional teaching strategy. Since the program is based on activity and on learning through discovery, the teaching material must be adapted to the individual differences in the children's ways of learning. The program is graded and structured to take the child's learning pace into consideration. The teacher is required to make a transition from collective (frontal) activity to group and individual activities, as well as a transition from teaching aimed mostly at imparting information to the development of ways of thinking and understanding how to learn.

d. The program is closely coordinated with mathematical skills with an emphasis on language development throughout, since children need language to react and represent what they discover in their environment.

In addition the program is characterized, on the one hand, by accumulation of concepts and on the other, by spirality which allows for constant repetition and extension of previously - treated concepts. It is important to note that the program neither deals with the concepts 'solid' and 'liquid', nor with the states of matter. Therefore, it was interesting to discover whether teaching centered around acquaintance with properties of objects and materials through sensory activation and classification activities, will enable transfer to properties of materials and classification problems in an area not dealt with in the program; and moreover whether such teaching will improve the understanding of the concepts 'solid' and 'liquid' as compared with children's achievements in the common programs. Our questions concentrated on the following points:

1. Does a difference exist in the discrimination between the concepts 'solid' and 'liquid' by children of the MATAL program as compared with children in the common program.
2. Will the learning results of the new program follow the developmental trend described in the previous paper (Stavy & Stachel 1984)?

The questions were examined on two levels: non verbal and verbal. The non-verbal level examined the ability to classify materials according to predicted behavior and their belonging to solids or liquids. The verbal level examined the ability to recognize similarity between solids and liquids and the

ability to define the concepts and explain the classification verbally.

Methodology

The sample comprised of 48 children in two kindergartens (age range 4;11-5;11, average age 5;4) with similar demographic conditions. One class employed the MATAL program, the other class used the common program. In these classes all 5 year olds and above were tested at the beginning of the school year (test 1) and at the end of the school year - 9 months later (test 2).

The Tasks

Definition of the concepts 'Solid'/'Liquid'

Students were first shown two solids, a rock and a stick, and were asked if there were any qualities common to both. If they did not use the term "solid" in their response, they were told that both objects are solid, and were asked if they knew what "solid" meant, and to give examples of other solids. Similarly, two liquids were then produced, tea and perfume, and the same sequence ensued: a description of the similarities, a definition of the word "liquid" and suggestion of other examples. These two solids and liquids served as reference items with which the rest of the materials were compared.

'Solid'/'Liquid' Classification

After the introductory questions, the students were presented with a set of 30 materials: 21 solids and 9 liquids. The solids included rigid items (a metal cube, a coin, a metal

pin, ice, chalk, chocolate, glass, a candle), soft items (cloth, cotton-wool, dough, plasticine, sponge, aluminum-foil, steel-wool, a metal spring) and powders (aluminum powder, sawdust, flour, sand, sugar). The liquids included thin liquids (gasoline, water, alcohol, chlorine water, corn oil) and dense liquids (honey, chocolate syrup, hair shampoo, mercury). After being shown the items, and handling them, the children were asked to classify each one either as a solid or as a liquid. They were also told that if one or more items did not belong in either group, they could classify them separately. Having classified the materials, they were asked to explain, why they had classified each item thus.

Predicting the Behavior of Materials

For this task, students were asked to predict which of 28 materials (excluding plasticine and candle) could or could not be piled up, and to justify their prediction

The tasks were presented in a standardized manner to all the children. They completed the tasks in two sessions. The questions were asked by one experimenter, while a second recorded the responses.

Findings

A. Verbal Tasks

Definition of the concepts 'solid' and 'liquid'

Previous findings (Stavy, Stachel 1984) indicate developmental changes across a wide age range (5;4-12;4) with distinctive progress from 5;4-6;10. The present study was aimed at investigating to what extent kindergarten children°s ability to recognize similarilty between different solids or different liquids changes as a result of the school program. We did not expect children to relate precisely to solids and liquids: the intention was to investigate whether, in presenting two typical solids or liquids, we would evoke associations related to, or close to, the concepts 'solid' or 'liquid'.

Insert Table 1 about here

Table 1 indicates a development which occured in both groups during the year, with an increase in the ability to recognize similarity between liquids, as was expected from the findings of the previous study.

In addition, it seems that the MATAL program significantly accelerates the development of this ability. Referring to the description of similarity between liquids, there was no difference between the MATAL group and the control group. Children in both groups used descriptions such as: "They are like water" "Both are thin" "They have drops" "Both are drinks but you don't drink perfume" "They pour" "They roll". Furthermore, in the use of the word "liquid" there was no difference between the

groups at the beginning of the year (only 4% of the children used the word 'liquid'), while at the end of the year 62.4% of the MATAL group used the word "liquid" as compared with 37.4% of the control group and 56% of the children in first grade who used the word "liquid". These findings indicate the accelerating influence of the MATAL program on the ability to recognize similarity between liquids and on the extent of use of the word "liquid". Nevertheless, the use of the word 'liquid' to describe similarity still lags behind the ability to recognize similarity. Table 1 also indicates that, despite the advancement in recognition of similarity between liquids and solids which took place in the two groups during the year, recognition of similarity between solids is more difficult than in the case of liquids, and even the MATAL program did not have a significant influence on the childrens' achievements. Here too, use of the word 'solid' to describe similarity between solids, lags behind the ability to recognize the similarity, and is used much less in comparison with the word "liquid" (only 12.5% in the MATAL group). At the beginning of the year children used descriptions like "Both are hard" and at the end of the year they mentioned "Hard" "You feel with your hands that you cannot break it" "It is heavy" "Wood has weight and stones have weight","Neither are hollow".

The percentage of children who gave relevant definitions is also shown in Table 1.

Table 1 also indicates that the percentage of children in the two groups who defined the concept 'liquid' did not change in the course of the year; the majority could define the concept in the first test. On the other hand, with regard to the relevant definitions of 'solid', we observe a significant advantage on the part of the MATAL group (no significant difference between the groups in test 1). This indicates that the program significantly enhanced the ability to explain the concept 'solid'.

At the beginning of the year, children defined the concept as "Non pouring" "Hard, has a lot of strength" "Makes a litle noise and is a little heavy". At the end of the year, children defined it thus: "It cannot be broken", "A nicer word for hard is 'solid'","Can be touched" "It is not hollow, there is something in it."

To sum up, the findings indicate a significant difference between the groups in three areas:

1. Recognition of similarity between various liquids.
2. Ability to define the concept 'solid'.
3. Use of the word "liquid".

The difference in favor of the MATAL group can perhaps be explained in the following way: Recognition of similarity among different liquids is based on perceptual properties which are dealt with intensively and systematically in the MATAL program though not specifically with regard to the concept of 'liquid' per se. No similar significant difference was observed in the ability to recognize similarity between various solids, perhaps

because this ability requires a non perceptual distinction. Regarding the ability to define the concept 'solid' and the use of the word "liquid", there is also a signiticant difference in tavor of MATAL, perhaps because the program systematically fosters the development of language.

B. Non Verbal tasks

Predicting the behavior of materials

Children were asked to predict one behavior of different materials (their ability to be piled up) in order to check whether they are acquainted with the characteristic property or behavior of solids and liquids.

Insert table 2 about here.

Table 2 indicates that children are well acquained with the behavior of liquids, especially the thin liquids. With regard to solids, the rigid solids are more familiar to the children than non-rigid ones or powders. Nevertheless, even with the rigid solids children found it difficult to reter to round or thin objects like the chalk and the pin. Children thought that they might roll and disperse and thus could not be piled up. Similarly with powders, prediction in the first test was less precise in comparison with other solids, and despite the development which occured during the year the results still indicate that children experience difficulties with this task. Children thought that powders disperse and therefore could not be piled up. It is worthwhile noticing the high achievement of children in predicting the behavior of sand. It can be assumed

that this success stems from the experience children have with sand.

Classification of materials as 'solid' or 'liquid'

Quantitative description of classification

Table 3 describes the percentage of children according to classification of materials.

Insert Table 3 about here

Thin liquids

The thin liquids were correctly classified by the majority of children in the two groups. The percentage who classified thin liquids with solids is very small even in the first test, and remains the same in the second test without any difference between the groups. Only around 15% of the children related thin liquids to the intermediate group (which is neither 'solids' nor 'liquids'). In the first test the majority of children did not employ a consistent and systematic mode of classification and the classification was arbitrary and contextual; for example: "Chlorine water is liquid because it is transparent". Nevertheless, some of the children presumably possess an intuitive perception of the concept 'liquid' which serves as a basis for success in classification; for example: "Oil is liquid because it is like water" or "Chlorine water is liquid because it pours*".

* In Hebrew, the word "liquid" is equivalent to the word "pours".

Dense liquids

A reasonable percentage of the children in the first test (around 60%) related dense liquids to the group of liquids. This finding also supports the existence of an intuitive perception of the concept 'liquid'. With the influence of the MATAL program, a decrease is observed in the number of children who classified dense liquids with liquids; a significant difference is also found between the groups in the second test. (F = 3.857 p 0.056 S.D. = 0.3). Parallel to these findings, there is an increase in the number of MATAL children who related dense liquids to the intermediate group (F=6.662 p 0.013 S.D.=0.5). However. no similar change occured with regard to the percentage of incorrect answers - relating dense liquids to solids.

We can assume that the decrease in the percentage of children who related dense liquids to the group of liquids and the increase in the intermediate groups, stems from learning focused on observation which yields a finer distinction between the two groups of liquids, on the one hand, and from the idea that liquid is only a material which pours quickly on the other hand. These changes in relating to liquids points to a transition from a diffused undefined knowledge of the concept 'liquid' to a more defined approach, albeit still limited in scope.

Rigid solids

In the first test around 40% of the children succeeded in relating rigid solids to the group of solids. This may perhaps contradict the statement above that no systematic classification system was employed at this stage. The success may be partially explained by the following factors: a. classification conducted on an arbitrary contextual basis; b. classification on the basis of the elimination of liquid. This type of classification apparently characterizes children who treat the concept 'liquid' intuitively and also apply this type of treatment to the classification of solids, when they use justifications like "It is not 'liquidish'". With regard to the percentage of success in classifying rigid solids, there was no difference between the groups in the first and second test; around 35% related rigid solids to the intermediate group. There was no change during the year. Regarding the relation of rigid solids to liquids, around 20% related rigid solids to liquids in the first test. In the second test a significant difference was observed between the groups with a decrease in the percentage of MATAL children who classified rigid solids with liquids ($F=6.236$, p 0.016 S.D.=0.6). This finding also supports the assumption that the MATAL program helped improve the perception of the concept 'liquid', and this was expressed by the rejection of materials not included therein.

Non-rigid solids

Around 30% of the entire population related non-rigid solids to the group of solids with no differences occurring

between the groups during the year. In the first test 55% of the population related non-rigid solids to the intermediate group. A significant difference among the groups occured at the end of the year when more children from the MATAL group related non-rigid solids to the intermediate group ($F=4.383$ p 0.042 S.D=0.3). This increase is followed by a decrease in relating non rigid solids to liquids ($F=S.393$ p 0.064 S.D.=0.5). This phenomenon supports the above findings according to which the concept of liquid also crystallizes by means of the rejection of non-rigid solids. At the same time, no parallel extension of the concept 'solid' is observed as children do not classify non-rigid solids with the group of solids.

Powders

Success in classifying powders was extremely low. Only around 20% of the children related powders with solids in the first test, and there was neither a significant difference between the groups at the beginning of the year nor at the end. In contrast, a significant difference between the groups appeared in the second test when more children in the MATAL group related powders to the intermediate group ($F=3.804$ p 0.011 S.D.=0.5) and parallely less children in the matal group related powders to liquids ($F=7.016$ p 0.011 S.D.=0.75).

This finding also supports the previous ones which indicate the influence of learning on the development of the concept 'liquid'. A similar achievement to that of the MATAL group after learning, appeared in our previous study with school children

aged 10 (fifth grade). This fact attests to the enhancing influence of teaching on the development of the concept. Nevertheless, it should be noted that despite the considerable development which occurs with the influence of the program on the perception of the concept 'liquid', there are still children who even after learning continue to classify solids with various sub-groups of liquids and who do not even include dense liquids with liquids. No similar clear developmental trend can be observed with regard to 'solid', though from the children's justification of their classifications the beginnings of relevant relation to the concept can be recognized.

Qualitative description of classification

From the children°s justifications of their classification, it is obvious that in the first test the majority did not possess a system of classification related to the concepts 'solid and liquid'. Classification was generally contextual with no major difference between the groups. Children put liquid with one of the demonstration materials because of an immediate perceptual property e.g., color, place, or function, and changed the initial criterion while they were classifying, or were influenced by the materials presented to them.

One example of contextual classification was expressed thus: "Water belongs to perfume because it is also transparent". The same child classified solids with liquids (glass with perfume) with the explanation: "Because glass is transparent and perfume is transparent". Another example: "Dough belongs only with solids

because it is the color as the stone". For the same reason children classified materials into an intermediate group; for example colored alcohol belongs neither with liquid nor with solid because "there is nothing purple here." "Chocolate syrup and hair shampoo don't fit anything". On the other hand, in the repeated test, we witness qualitative differences in the classification. Among the MATAL children there is a tendency to use a classification system indicating a certain development both in relation to concepts and in the ability to classify, when they begin using more adequate criteria for the concepts 'solid' and 'liquid' and perform the classification more consistently and systematically as compared with the initial state and the achievement of the control group. Children related solids to the group of solids by using better-defined criteria such as: heaviness, hardness or by process of elimination of liquid. These were expressed in such justifications as: Metal cube - "It is solid because it is terribly heavy". Ice - "It is solid because it is heavy and hard". Chocolate - "It is the same inside as outside" (full). Chocolate - "It does not drip". Sawdust - "It doesn°t pour". Oil - "Belongs to liquid because it pours and you can treat it like water". Alcohol - "It also drips, it moves." The intermediate group included materials which, according to the children's criteria, did not fit either the group of liquids or the group of solids: e.g. Chocolate - "It is not hard, nor does it drip". Sand - "It moves but doesn°t drip". Cottonwool - "It doesn°t drip and isn°t solid, you can crumble and tear it". Sand

- "It doesn°t drip and isn°t solid but it pours." Sugar - "It pours, not like water but in another way". Sawdust - "Not edible and doesn°t drip." Honey - "Until it moves it takes a long time".

Discussion.

1. Knowledge of properties - a basis for classification

Generally, from the first test children proved that they know the characteristic property of materials - their ability to be piled up. It seems that there is a relationship between recognition of this property and the ability to classify materials as solids or liquids. It transpired that the children were better able to predict the behavior of rigid solids than that of non-rigid solids; they succeeded to a lesser extent in predicting the behavior of powders. From the first test, all the children could predict the behavior of thin liquids, and the majority were acquainted with the behavior of dense liquids. This picture is similar to that related in the classification of solids and liquids. The relationship between knowledge of the property and the ability to classify it as a 'solid' or 'liquid' is salient with regard to specific materials like sand, with which children are quite familiar; 83% could predict its behavior correctly as compared with 33% success in predicting the behavior of other powders. Knowing its behavior helped the children to classify sand correctly in all the tests. Conversely, prediction of the metal pin was very low compared with the rest of the rigid solids, so was its classification as a solid. From these

examples it seems that the more children are acquainted with the properties relevant to the concept, the more successful they are with correct classification. Nevertheless, it must be emphasized that knowledge of properties alone does not guarantee correct classification. This fact points to the importance of experimentation with properties of objects in kindergarten as a basis for the development of the understanding of concepts.

2. The influence of learning on the understanding of the concepts 'solid' and 'liquid'

Young children learn about objects and their properties through observation and interaction with them, and by following the results of their actions. Learning the various properties of objects, and recognizing similarities and differences among them creates a basis for classifying them. As the ability to recognize and generalize develops, the possibilities for classifying objects in a greater number of groups also increase. Initially, the child is dependent upon the observable properties of the objects; as he grows he gradually frees himself of this dependence on perceptual properties and can organize phenomena using essentally logical criteria (Werner 1961, Bruner 1964, Sigel 1953, 1964).

In our research we refrained from asking the child directly about the concepts in order to avoid a priori exposure to the final product of the developed concept (thus ignoring the dynamic aspect of the process itself) since the need to concentrate on

the word does not take into account the perception and the intellectual elaboration of the sensory material which shapes the concept. Within the MATAL program children learn to identify various properties of objects, they learn to recognize similarities and differences to generalize and classify and to use language accordingly. It is evident from the findings that the development of thinking skills enhances the understanding of the concepts 'liquid' and 'solid' and the ability to classify objects. It is important to restate that although the program does not treat the concepts 'solid' and 'liquid' directly but rather focuses on developing the above-mentioned skills through content which matched the perceptual abilities of kindergarten children, it appears that mastery of these skills has an influence on the development of new skills on a level of abstraction higher than that treated in the original content. With regard to the developmental trend of classification, it is important to note that in the first test we are faced with a phenomenon of diffuse, amorphic and inconsistent classification which characterizes the behavior of children at this age. Even though children are familiar with the word 'liquid' to describe behavior of materials (in Hebrew), there exists a difference between the argument that something pours and the argument that it belongs to the group of pourable materials. The first argument is immediate and describes a phenomenon in action, while the second is more inclusive. It includes the intellectual ability to establish a group of liquids; for example, the ability

to relate to a certain group of materials according to their specific properties when these are not necessarily perceived spontaneously through the senses.

In the second test, which took place after teaching, we witness the development of a clear and consistent system of classification, where materials are grouped around the core concepts 'solid' and 'liquid'. This is particularly, evident with regard to the group of liquids, when the core concept 'liquid' is perceived by children as related to thin liquids only (following water as a model). As a result, we witness the fact that dense liquids and solids, which were included in the first test with the liquids, were excluded in the second test by the MATAL group. Since the concept 'solid' is more abstact than 'liquid' (as the perceptual elements on which it is built are not as visible as those of 'liquid' which has perceptual elements more constant and unified than those of solids), the variance of solid is therefore greater and its deviation from the concept is stronger. The core concept 'solid' is perceived by children as relating to an unchanging shape or state; therefore, it is relatively more limited than liquid. To conclude, we can say that at the kindergarten level, materials are classified into two groups vis-a-vis the concepts 'solid' and 'liquid': two polar core groups extremely limited so that any material which cannot be included therein is relegated into an intermediate group which includes materials regarded simultaneously as solid and liquid. It is important to note that the cores of both these concepts are

not perceived as being dichotomous and the criteria children use are not mutually dependent; e.g., what is not regarded as liquid is not necessarily solid, and vice versa. Moreover, it seems that the core concept 'liquid' is clearer and better defined than the core concept 'solid'. This system of classifying materials into core groups and an intermediate group which begins in kindergarten is maintained steadily for many years and probably ends after a specific learning of these concepts in Junior High School.

The findings point to the importance of fostering skills of observation, thinking and classification as factors which may contribute to the enhancement and advancement of development of these concepts.

It is interesting to note that the improvement in the classification ability of liquids in the MATAL group was followed by an increase in the use of the word 'liquid', to indicate similarity among different liquids. In addition, the qualitative change in classification - the transfer from contextual classification to a systematic one with the use of a consistent and relevant criterion (especially for solids) - was accompanied by a significant improvement in the ability to define 'solids'.

These phenomena demonstrate the strong corollary between the devlopment of concepts and the development of language (Donaldson 1978).

Table 1: Percentage of Children Recognizing Similarity between Different Liquids and Solids, and Percentage of Children who Defined the concepts 'Solid' and 'Liquid.'

Group		MATAL		CONTROL	
Task	Test	1	2	1	2
Similarity between Liquids		16	83*	8	58
Similarity between Solids		0	33	4	33
Defining Liquids		91	91	83	83
Defining Solids		33	66**	12	16

* $p = 0.056$

$= 3.630$

** $p = 0.0013$

$= 10.3714$

Table 2: Percentage of Children According to Correct Prediction of Behavior of Materials

Group		MATAL		CONTROL	
Material	Test	1	2	1	2
Thin Liquids		100	100	97	100
Dense Liquids		90	85	90	89
Rigid Solids		67	82*	69	70
Non-Rigid Solids		55	67	65	61
Powders		43	65	58	70

* Two-way analysis of variance indicates a significant ditterence between the groups in the second test only with regard to rigid solids (p 0.016 F=6.269)

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Notes

1. The concepts °solid° and 'liquid' serve within the frame of theories aimed at describing the structure and behavior of materials. In the majority of physics text-books used in schools, materials are classified as 'solid' or 'liquid' according to their behavior. Scientists usually define solids and liquids in accordance with the molecular organization of matter. In this study we will only use definitions related to the behavior of materials, and not to their molecular organization. (Thus, we took the liberty of including, for example, glass with solids and not with solid-liquids, as defined by scientists.)